PROPOSED SPECIFICATIONS FOR POLYMER COMPOSITE MATERIALS FOR REHABILITATING CONCRETE STRUCTURES

PREPARED FOR
GEORGIA DEPARTMENT OF TRANSPORTATION

BY

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1 SCOPE

This information defines the proposed requirements for polymeric composite material systems intended for use for rehabilitating reinforced concrete structures. This information is provided to the Georgia Department of Transportation (GDOT) for their use in the development of a specification.

2 DEFINITIONS

2.1 GENERAL

Definitions of terms pertaining to this proposed specification shall be those of ASTM D 883 Terminology Relating to Plastics, ASTM D3878 Standard Terminology of High- Modulus Reinforcing Fibers and Their Composites, and ASTM D907 Standard Terminology of Adhesive. When definitions of terms are conflicting, those of ASTM D3878 shall have the precedence over those in ASTM D883. Definitions of relevant and additional terms are given below.

Acceptance Test-a test, or series of tests conducted by the procuring agency, or an agent thereof, upon receipt to determine whether an individual lot of of materials conforms to the purchase order or contract or to determine the degree of uniformity of the material supplied by the vendor, or both. (ASTM D907)

Adhesive-a substance capable of holding materials together by surface attachment. (ASTM D907)

Design Value-the value above which at least 95% of the population is expected to fall with 75% confidence.

Field-Manufactured Composite System-Fibers in the form of tows, yarns, or fabrics impregnated in the field with resin either manually or by means of an automatic equipment.

Fillers-particulate materials added to the resin or adhesive material to alter its properties, performance, and/or cost.

Qualification Test-a series of tests conducted by the procuring activity, or an agent thereof, to determine conformance of materials, or materials system, to requirements of a specification which normally results in a qualified products list under the specification. (ASTM D907)

Matrix-the material compound in which the fiber system of the composite is embedded

Resin-an organic polymer possessing indefinite and often high molecular weight and a softening or melting range that exhibits a tendency to flow when subjected to stress.

Shop-Manufactured Composite Systems-composite material systems, in the form of plates, shells, or other shapes, that can be bonded in the field to the surface of the rehabilitated member using adhesive.

3 MATERIAL DATA FOR SUBMISSION AND QUALIFICATION

3.1 Contractor shall furnish GDOT information pertaining to the polymer matrix or adhesive system, reinforcement, and composite systems. This information shall be based on previous use demonstrating satisfactory performance under specified conditions and shall include the commercial designation, name of manufacturer, and Material Safety Data Sheet (MSDS), prepared in compliance with the Federal OSHA Hazard Communication Standard 29 CFR 1910.59, of each raw material as well as the composite system.

3.2 Contractors shall submit for approval evidence of an acceptable supplier quality control procedure for control of raw materials and manufacturing processes of the composite system. The quality control procedure shall include, but is not limited to, the use of raw raw material procurement specifications, the quality standards for the final product, in-process inspection and control procedures, test methods, sampling plans, accept and reject criteria, and record keeping.

3.3 Contractor shall submit for approval testing results, generated by independent laboratories approved by GDOT, showing that raw materials and the composite system possess physical and mechanical property values determined by a testing laboratory approved by GDOT. For each property value, the number of batches from which test specimens were drawn, the number of tested specimens from each batch, the mean value, the minimum value, the maximum value, and the coefficient of variation shall be reported.The minimum number of tested samples shall be 10.

3.4 When cured in a manner recommended for rehabilitation, matrix material used in the composite system shall conform to the requirements of Table 1:

Table 1: Required Matrix Properties

Test	**Requirement**	**Test Method**
Density	Specified by manufacturer	ASTM D792
Gel Time	Specified by manufacturer	ASTM D2472
Cure Behavior	Specified by manufacturer	ASTM D4473
Moisture Equilibrium	Less than 3%	ASTM D570
Glass Transition Temperature	Greater or equal $70°C(158°F)$	ASTM D3418
Barcol Hardness	Greater or equal 50	ASTM D2583
Tensile Strength	Greater or equal 8 ksi	ASTM D638
Tensile Modulus	Greater or equal 400 ksi	ASTM D638
Tensile Strain	Greater or equal 2 %	ASTM D638

3.5 Adhesive material used in conjunction with shop-manufactured composites shall conform to the requirements in Table 2

Table 2: Required Adhesive Properties

Test	Requirement	Test Method
Density	Specified by manufacturer	ASTM D792
Gel Time	Specified by manufacturer	ASTM D2472
Cure Behavior	Specified by manufacturer	ASTM D4473
Moisture Equilibrium	Less than 3%	ASTM D570
Glass Transition Temperature	Greater or equal $70°C(158°F)$	ASTM D3418
Barcol Hardness	Greater or equal 50	ASTM D2583
Tensile Strength	Greater or equal 4 ksi	ASTM D638
Tensile Modulus	Greater or equal 400 ksi	ASTM D638
Tensile Strain	Greater or equal 1 %	ASTM D638
Shear Strength		ASTM E229
Peel Resistance		ASTM D903

3.6 Carbon fiber reinforcement forms to be used in a composite system shall be identified according to the classifications defined in Table 3 :

Table 3: Classes of Carbon Fiber Reinforcement Form

Fiber Form	Description
Class CY-Grade n	Carbon yarn having a thousand filaments
Class CT-Grade n	Carbon tow having a thousand filaments
Class CF	Kintted, woven, nonwoven, braided, or other form of fabrics constructed from Class CY or Class CT
Class CP	Prepreg constructed from Class CY, Class CT, or Class CF impregnated with resin

3.6.1. Contractor shall furnish sufficient information describing the fiber orientation, fiber dimensions, and fiber surface treatments of the reinforcement form.

3.6.2. The properties of the carbon fiber reinforcement form used the composite system shall conform to the requirements of Table 4.

3.6.3. The composite system shall conform to the requirements of Table 5.

3.6.4. The glass transition temperature determined in accordance with ASTM D3418, the tensile properties of the composite in the direction of interest determined in accordance with ASTM D3039, and the tensile and flexural properties of the resin determined in accordance with ASTM D638 and ASTM D790, respectively, after conditioning in the following environments shall retain 85% of the design property values obtained from an independent laboratory approved by GDOT :

(a) Water: Samples shall be immersed in distilled water having a temperature of $100° \pm 3°F$ and tested after 1,000, 3000, and 10,000 hours of exposure.

(b) Alternative ultraviolet light and condensation: Samples shall be exposed to 100 alternating ultraviolet lumen intensity and condensation humidity cycles using

Table 4: Required Fiber Properties

Fiber Form	**Property**	**Requirement**	**Test Method**
Class CY and Class CT	Density	As specified by manufacturer	ASTM D3800
	Tensile Strength	500 ksi minimum	
	Tensile Modulus	29,0000 ksi	
	Tensile Strain	1.4 % As specified by manufacturer	
Class CF	Areal Weight	As specified by manufacturer	
Class CP	Areal Weight	As specified by manufacturer	
	Volitile Content	As specified by manufacturer	ASTM D3530
	Viscocity Profile	As specified by manufacturer	ASTM D4065

Table 5: Required Composite System Properties

Test	**Requirement**	**Test Method**
Density	Specified by manufacturer	ASTM D792
Fiber Volume	30%	ASTM 2584
Void Volume	5% maximum	ASTM D2734
Glass Transition Temperature	Greater or equal $70^{\circ}C(158^{\circ}F)$	ASTM D3418
Moisture Content at Equilibrium Condition	3%	ASTM D5229
Tensile Strength	3 kip/in minimum 8 ksi	ASTM D3039
Tensile Modulus	9,000 ksi minimum	ASTM D3039
Tensile Strain	1% minimum	ASTM D3039

FS 40 UV-B bulbs in an apparatus meeting the requirements of ASTM G53. Each cycle shall consist of four hours at 140o F and four hours of condensation exposure at $104^{\circ}F$. Samples shall be tested within two hours possible after removal from the apparatus.

(c) Salt Water: Samples shall be conditioned according to ASTM D1141.

(d) Alkali: Samples shall be immersed in a saturated solution of calcium hydroxide (PH 9.5) at ambient temperature of $73^{\circ} \pm 5\circ$ for 1,000, 3,000, and 10,000 hours prior to testing. The PH level shall be monitored, and the solution shall be maintained as needed.

(e) Freeze-Thaw: Composite panels or coupons shall be exposed to 100 repeated cycles of freezing and thawing in an apparatus meeting the requirements of ASTM C 666 “Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing.”

4 STORAGE AND HANDLING

4.1 Raw materials shall be stored in cool and well ventilated facilities at a temperature not exceeding $70^{\circ}F$ in tightly closed containers sealed to prevent infiltration of moisture and possible contaminants. Raw materials shall be stored off the ground and away from sources of moisture, direct sunlight, heat, sparks, and flame and from any alkaline or oxidizing materials. Resin and adhesive materials shall be surrounded by dikes to to contain leaks or spills. Additional storage requirements specified by raw material suppliers shall be followed.

4.2 In the event of a spill or leak, the affected area shall be soaked up with suitable nonreactive absorbent material and pumped into suitable containers for disposal.

4.3 Disposal of raw materials shall be in compliance with Federal, State, and local Government Regulations. Hardeners, catalysts and uncured resins and gel-coat may contain flammable solvents and/or several chemicals that are likely to be hazardous wastes.

5 FIELD APPLICATION

5.1 SURFACE EVALUATION

Concrete surfaces to be repaired with composite materials shall exhibit a minimum of 200 psi pullout strength when tested in accordance with Appendix A of "Use of Epoxy Compounds with Concrete" prepared by ACI Committee 503.

5.1.1 Protrusion higher than 1/16 inches shall be removed and holes and depressions greater than 1/16 inches in the concrete surface to be repaired shall be filled flush with mortar approved by the Georgia Department of Transportation.

5.1.2 Corroded reinforcing steel or prestressed tendons shall be repaired by mechanically cleaning the rust.

5.1.3 The shape of a damaged structure shall be restored with new structural concrete or mortar approved by the Georgia Department of Transportation.

5.1.4 Cracks wider than 0.01 inches shall be epoxy injected.

5.1.5 Corner edges shall be rounded to a minimum radius of 1 inch.

5.1.6 The concrete surface to which composite materials is to be applied shall be sand-blasted to remove any deleterious materials such as laitance, dust, oil, or loose materials. All residue from sandblasting shall be removed with compressed air only. When abrasive blasting is not an option due to environmental restrictions, grit blasting, where grits and debris are collected by a vacuum system shall be used. When hydroblasting cleaning techniques are used, the concrete surface shall be allowed to dry prior to any subsequent repair step.The condition of the final concrete surface shall be approved by GDOT.

5.1.7 A penetrating epoxy primer may or may not be applied to the clean concrete surface prior to the repair application with composite materials. The requirement for priming will depend on the composite system used. When used, priming shall be performed only when the air temperature is between 40o F and 90o F, the relative humidity is less than 90%, the concrete surface temperature is more than $5^{\circ}F$ above the dew point, and the concrete surface moisture content is no greater than 4%.

5.2 COMPOSITE MATERIAL APPLICATION

5.2.1 An application plan shall be submitted and approved by GDOT before any work begins.

5.2.2 Composite materials shall be applied only to a primed tack-free (as applicable) concrete surface that is clean and free of dust.

5.2.3 Composite systems to be used for strengthening reinforced concrete structures shall be balanced and symmetric.

5.2.4 Adjacent layers of reinforcement withing one layer shall be lapped. The overlap length shall be the greater of eighty times the layer thickness or 4 inches, whichever controls.

5.2.5 Reinforcement forming multiple layers shall be staggered not be terminated at the same location.. The edge distance between two subsequent layers shall be greater than 2 inches.

5.2.6 Fiber misalignment with respect to a direction specified by the engineer shall not be greater than 3 degrees.

5.2.7 Elapsed time between mixing and application of the first ply and also between any two successive plies shall be within a a time period not exceeding the gel time specified in Tables 1 or 2, as applicable.

6 RECORDS

During the rehabilitation of concrete structures with composite materials, the Contractor shall record the following data:

6.1 Name of the project.

6.2 Date of rehabilitation

6.3 Ambient air temperature and relative air humidity measured in the shade at commencement of work, every two hours thereafter, and at the end of work.

6.4 Concrete surface temperature and relative humidity at the time of rehabilitation.

6.5 The compressive strength of the concrete to be strengthened.

6.6 The commercial designation, name of manufacturer, date of manufacturing, and the manufacturer lot number as shown on the shipping label for each component used to form the binding resin matrix.

6.7 The commercial designation, name of manufacturer, date of manufacturing, and the manufacturer lot number as shown on the shipping label for the reinforcing fibers, fabric, or prepreg as applicable.

7 ACCEPTANCE CRITERIA

7.1 The rehabilitated structure shall be inspected visually and also by performing tap test with a coin or a small piece of metal. An inspection technique using thermography is preferred. The rehabilitated structure shall be free of any defects (e.g. voids, bubbles, and delamination). In the presence of such defects, the Contractor shall submit a repair plan to be approved by the GDOT at least 15 days before any repair work begins.

7.2 The Contractor shall be responsible for conducting direct composite pull-out tests referenced in Section 5.1 to be performed on areas adjacent to the actual rehabilitated area after the manufacturer's recommended curing time period. The test area shall have the same number of plies and/or ply orientations as those of the rehabilitated areas; and shall not affect the rehabilitation in any manner. representatives of the . The required number of composite pull-out tests shall be 3 for every $250ft^2$ of rehabilitated area. These tests shall demonstrate that failure always occurs in either the substrate or along the bond line with a minimum average tensile stress of 300 psi.

7.3 The Contractor shall be responsible for conducting tensile material property tests in the primary fiber direction. These tests shall be in accordance with ASTM D3039 and the results shall meet the requirements of Table xx

7.4 The Contractor shall be responsible for conducting glass transition temperature tests in accordance with ASTM E 1356. A minimum of three tests for every $250ft^2$ of strengthened area shall be required. Results shall meet the requirements of Table 1 or 2, as applicable